Taxonomic Revision of *Sagitta robusta* and *Sagitta ferox* Doncaster, and Notes on Their Distribution in the Pacific

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The material for this study was provided by the monthly cruises of the California Cooperative Fisheries Investigation (CalCOFI) during 1954 and 1958, and by the following expeditions of Scripps Institution of Oceanography in the Pacific Ocean: Northern Holiday (1951), Shellback (1952), Capricorn (1952–53), Transpac (1953), East Tropic (1955), North Pacific (1955), POFI (1955), Troll (1955), Chinook (1956), Equapac Horizon (1956), Equapac Stranger (1956), Downwind (1957), Tethys (1960), and a few samples from the Naga (1959–61).

Thirty species of Chaetognatha were found in the plankton samples from the Pacific expeditions; 24 of these were observed also in the 2,000 samples examined from the area covered by the CalCOFI cruises off California in 1954 and 1958. The identities of two of the species found, *Sagitta robusta* Doncaster and *S. ferox* Doncaster, are confused in the literature. The principal aim of this article is to discuss and establish the valid taxonomic characteristics of these two species prior to publishing a study of the distribution and abundance of the chaetognaths in the area of the CalCOFI cruises.

TAXONOMIC NOTES

A clear statement on the systematics of these species was perhaps difficult, in the past, since only a small number of specimens was available. The various Scripps expeditions cover an extensive distributional area in the Pacific. The numerous plankton samples collected are generally well preserved, providing good material for an accurate taxonomic study. A large number of *S. robusta* and *S. ferox* specimens, therefore, have been carefully examined.

S. robusta Doncaster and *S. ferox* Doncaster could be included in a taxonomic group with their closest relatives *S. hispida* Conant, *S. helenae* Ritter-Zahony of the Atlantic, and *S. bipunctata* Quoy and Gaimard, a cosmopolitan species. They have strong, firm bodies, because of the well-developed muscles, small lateral fields, large heads, and conspicuous collarettes.

S. robusta and *S. ferox,* although very closely related, can be easily distinguished by several characteristics which appear consistently in each. These two species are found in equatorial and tropical Pacific waters, spreading to the subtropical region. They both have a firm, opaque body, strong muscles, large head, and a well-developed collarette. One of the species is smaller than the other. The smaller has the characteristics of *S. robusta* Doncaster and the larger those of *S. ferox* Doncaster. However, the size notations recorded in this study do not agree with the size Doncaster (1903) reports in the original description. This fact shows that perhaps for some reason the size notations in the original descriptions are erroneous. Similar discrepancies are found in successive revisions.

The taxonomic confusion in the literature is explained by the fact that Doncaster (1903) originally applied one series of characteristics to the smaller species and the other series to the larger. His first description of *S. robusta* and *S. ferox* is incomplete; nevertheless a few well-defined characteristics given by Doncaster provide good reason for separating the two species.

The main distinctive characteristics for both *S. robusta* (a) and *S. ferox* (b) in the original description (Doncaster 1903) are as follows:

(a) "posterior fins reach the seminal vesicles,"

(b) "do not quite reach the seminal vesicles";

(a) "ovaries extremely long and extend in fully mature specimens to the anterior transverse septum,"

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(b) "long as in *S. robusta,* but do not quite reach the front end of the trunk cavity";
(a) "seminal vesicles touch both posterior and tail fins, project somewhat,"
(b) "project slightly";
(a) "hooks 7–8, usually 8,"
(b) "hooks 5–6."

Doncaster also gives *S. robusta* a very important characteristic; namely "the anterior fin's front end is opposite the posterior end of the abdominal ganglion." This distinctive characteristic is the clue for a clear-cut separation of the two species.

Size is the one difference between Doncaster's diagnosis and those studied here. He gives a mature size of 16 mm for *S. robusta* and of 12 mm for *S. ferox,* whereas the specimens from the Pacific and China Sea collections with the characteristics of *S. ferox* mature when at least 16 mm in length, and specimens with the characteristics of *S. robusta* when at sizes 8–12 mm.

This size discrepancy could be a misprint in the original description, and has apparently been the cause of the controversy regarding the identity of these species and the resultant mistaken identifications which have been published. Apparently many authors separate these species by size alone, disregarding the other anatomical features. For this reason, specimens with the characteristics of *S. ferox* have been considered as *S. robusta* and vice versa. The belief that the sizes were inadvertently transposed from one species to the other in the original description is supported by the fact that the specimens from the Pacific Expeditions consistently have the characteristics of *S. robusta* with sizes 8–12 mm and *S. ferox* with a size of 16 mm.

Descriptions of *S. robusta* and *S. ferox* found in material from the Pacific and China Sea collections follow.

Sagitta robusta Doncaster

Total length when mature, 8–12 mm.

Average % tail length in relation to the total length, 27.5.

Head large, but smaller than in *S. ferox* (Fig. 1).

The clove-shaped body is strong, firm, broad, of nearly uniform width from the neck to the tail septum. It is opaque because of the strong longitudinal muscles (Fig. 2*d*). Lateral fields small.

Collarette well developed, extends from the head to the posterior end of the ventral ganglion, spreading to the tail as a thin layer that becomes thicker in front of the anterior end of the seminal vesicles.

The corona ciliata was not studied because it could not be seen clearly in preserved material; therefore it was of small value for identification purposes.

Gut diverticula present and rather conspicuous.

The anterior fins are shorter than the posterior fins. They extend up to the level of the posterior end of the ventral ganglion. They are wider than in *S. ferox* and no rayless zone is present.

The posterior fins are rounded. They lie more on the tail than on the trunk. About ⅔ of the length of the fin lies on the tail segment. The posterior fins are wider at a point slightly behind or in front of the tail septum. A small rayless zone appears at the internal portion of the fins, in front of the tail septum, by the external openings of the female organs.

The distance between both the anterior fins and the posterior fins is longer than in *S. ferox.*

The seminal vesicles (Fig. 3) are conspicuous even in the young species. They touch both tail fin and posterior end of the posterior fins. They

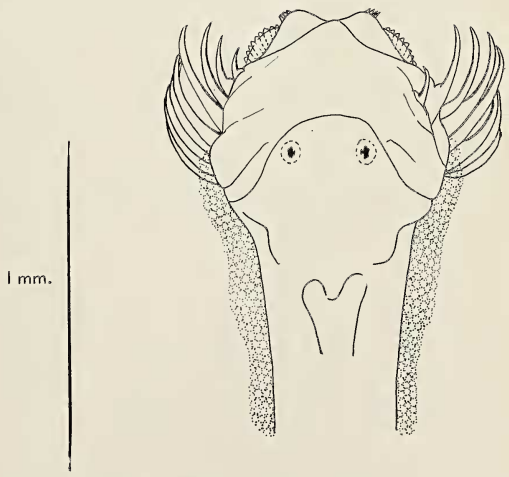

FIG. 1. Head of *S. robusta* Doncaster.

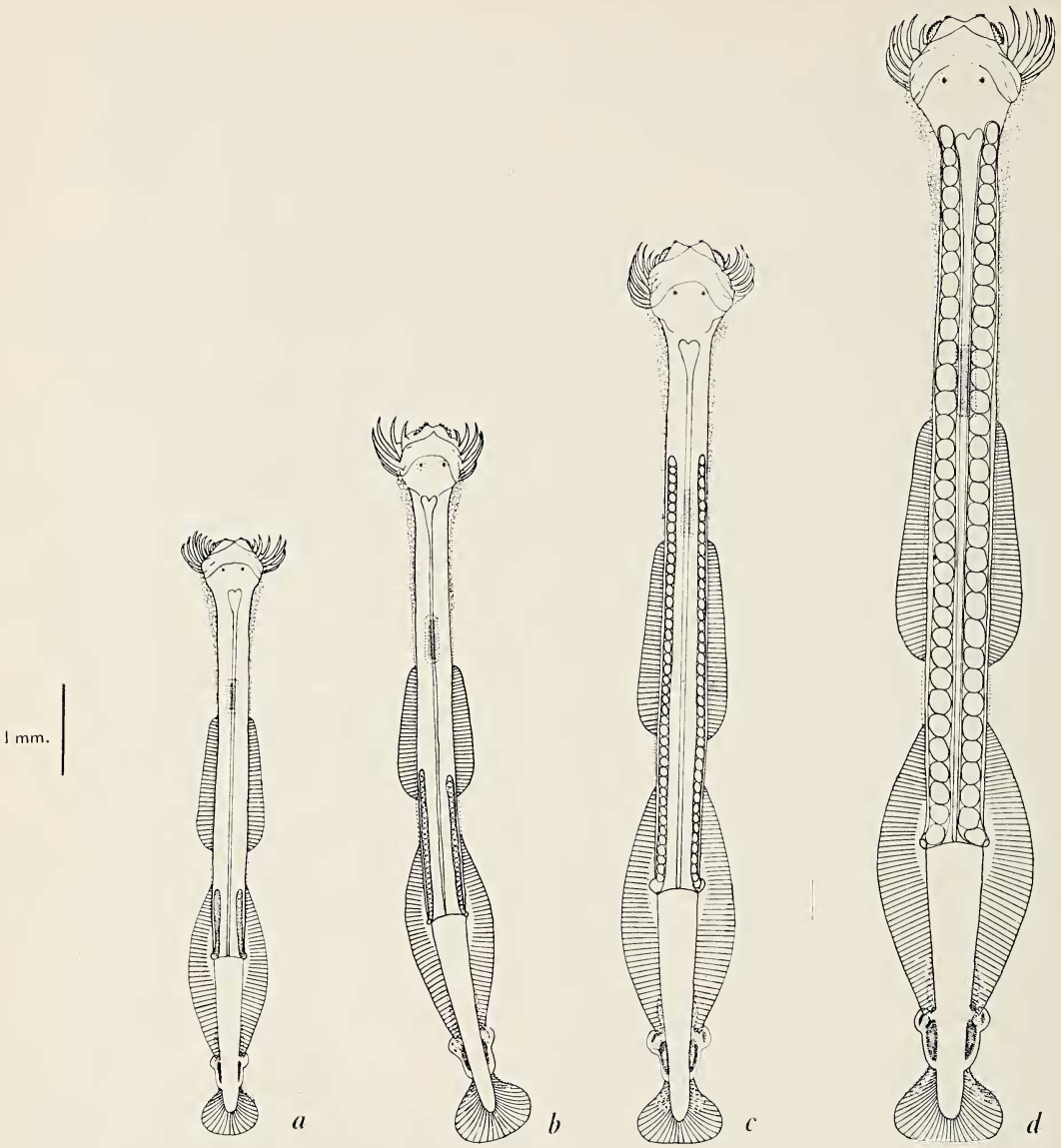

FIG. 2. *S. robusta: a,* 6 mm long, maturity stage I; *b,* 7.6 mm long, maturity stage II; *c,* 9.6 mm long, maturity stage III; *d,* 12 mm long, maturity stage IV.

have a well-developed head and a voluminous posterior sperm sac, and rupture occurs ventrally at the anterior lateral side. The seminal vesicles in *S. robusta* resemble in shape those of *S. bipunctata.* In both *S. robusta* and *S. bipunctata* there is swelling of the collarette tissue on the tail in front of the anterior end of the seminal vesicles, but in *S. bipunctata* the posterior fins do not touch the the seminal vesicles as in *S. robusta,* and the distance between the anterior end of the seminal vesicles and the posterior end of the posterior fins is occupied by the particular swelling of the collarette tissue.

The ovaries are long, reaching from the neck

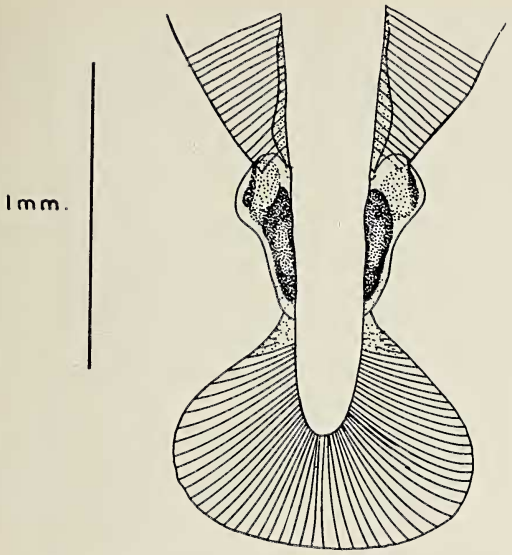

FIG. 3. *S. robusta,* seminal vesicles, ventral view.

to the anterior septum in the fully mature specimens. The ova are round and arranged in one row in the ovaries (Fig. 4).

Hooks 7–8. This notation is unusually constant.

Anterior teeth 6–9.

Posterior teeth 10–15.

The eye pigment is concentrated as in Figure 5. The shape of the pigmented area is similar in both *S. robusta* and *S. ferox* but in *S. ferox* the longitudinal axis of the ellipse is longer in relation to the transverse axis.

S. robusta from the CalCOFI and from part of the Shellback samples mature when 7–8 mm in length. The mature specimens are smaller at the eastern edge of the distributional area, that is, off the southern part of Baja California and the southern part of Mexico. This fact is probably due in many cases to an increase in temperature.

Sagitta ferox Doncaster

Total length when mature, 16–18 mm without tail fin.

Average % of tail segment in relation to total length, 26.5.

The body is rigid, firm, with the same width from the neck to the tail septum. The longitudinal and transverse muscles are strong. The lateral fields are narrow. In general resembles a clove, as does *S. robusta,* but larger in size and with well-defined characteristics which permit easy differentiation of the species (Fig. 6*d*).

The head is large (Fig. 7).

The eyes are as shown in Figure 8.

The collarette is well developed, extending from the head to the anterior end of the anterior fins.

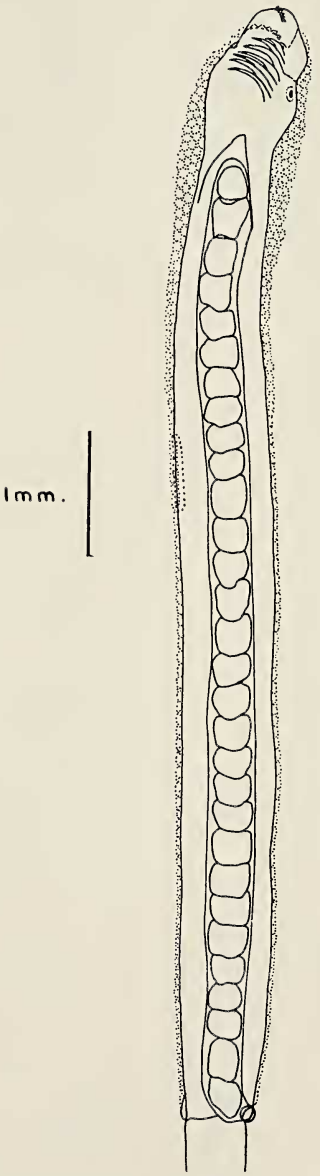

FIG. 4. *S. robusta,* lateral view of left ovary. Detail of the disposition of the ova.

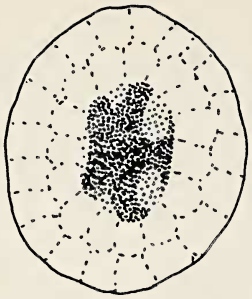

FIG. 5. *S. robusta*, right eye.

Anterior fins reach the level of the middle of the ventral ganglion. They are longer than the posterior fins. No rayless zone is present. They are narrower and longer in comparison to the total size than in *S. robusta*.

The posterior fins are rounded and triangular in shape. They are wider at a point behind the tail septum. They extend approximately the same distance on the trunk as on the tail, or slightly more on the tail. They present an interior rayless zone which extends from the level of the tail septum to the final anterior end of the fins.

Both anterior and posterior fins are rather close laterally.

The seminal vesicles almost touch both the posterior fins and the tail fin, but are not as conspicuous in the early stages as in *S. robusta*. However, they are very noticeable when full or at the last stage of maturity of the male organs. The rupture occurs by a lateral opening (Fig. 9 *a, b*).

The ovaries reach the neck region completely filling the body cavity when fully mature. The ova when ripe, are wider than long and are dorso-ventrally arranged in two or three rows. (Fig. 10.)

Gut diverticula present.

MATURITY STAGES

Fig.	Stage	*Sagitta robusta* Doncaster		*Sagitta ferox* Doncaster	
		male organs	female organs	male organs	female organs
2*a*, 6*a*	I	testes begin to appear; seminal vesicles begin to appear at a precocious age	ovaries as thin tubes, reaching up to the anterior end of posterior fins	testes begin to appear; no trace of seminal vesicles	ovaries as fine tubes, reaching up to the anterior end of the posterior fins
2*b*, 6*b*	II	tail filled with sperm; seminal vesicles conspicuous	ovaries reach anterior end of anterior fins	tail filled with sperm; seminal vesicles begin	ovaries reach anterior end of anterior fins
2*c*, 6*c*	III	seminal vesicles full	ovaries reach up near to the neck	tail partially discharged; seminal vesicles full	ovaries reach to a point between the neck and the ventral ganglion; they are wider; ova large and arranged dorso-ventrally in two or three rows
2*d*, 6*d*	IV	seminal vesicles turgid, discharging and still conspicuous	ovaries reach the anterior septum; ova in one row	tail empty; seminal vesicles discharged	ovaries reach the neck, filling the body cavity

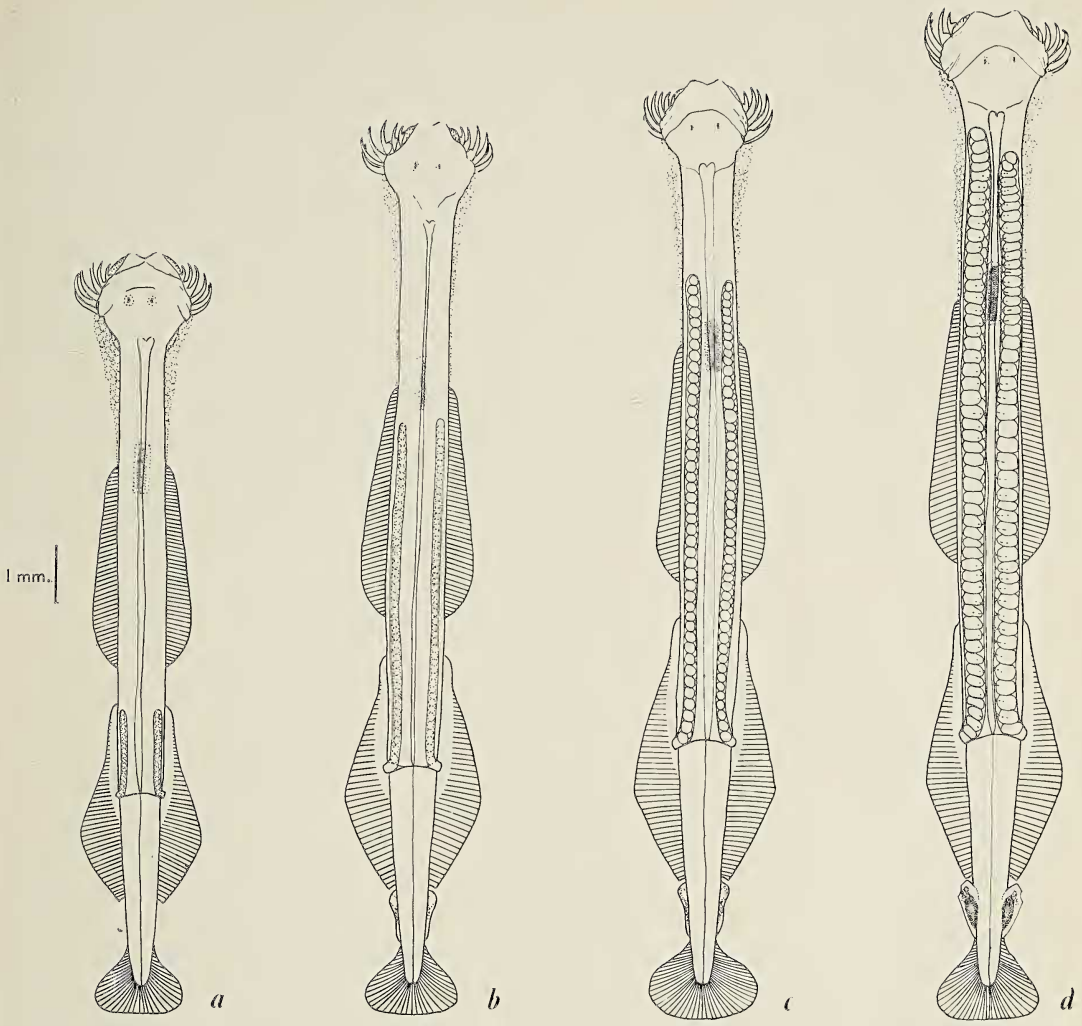

FIG. 6. *S. ferox* Doncaster: *a,* Up to 12 mm long, maturity stage I; *b,* 14 mm long, maturity stage II; *c,* 15 mm long, maturity stage III; *d,* 16 mm long, maturity stage IV.

Hooks 5–6, usually 6, and this notation appears particularly constant.

Anterior teeth 7–10, usually 9.

Posterior teeth 12–14.

Specimens of *S. robusta* from the Naga Expedition are fully mature when 12 mm in length. Specimens from the Equapac Horizon and Stranger are mature when 10 mm, and from the CalCOFI and Shellback area when 7–8 mm. In the measurements the tail fin was not included.

REVISION OF LITERATURE AND DISCUSSION OF TAXONOMY

Doncaster (1903) gives a few well-defined characteristics for *S. robusta* and *S. ferox,* but an incomplete description (Table 1).

Fowler (1906) redescribes both in more detail and also gives their respective distribution areas and temperature ranges on pages 42, 45, 55, 69, 72, 76, 77, and 78. He states for *S. ferox:*

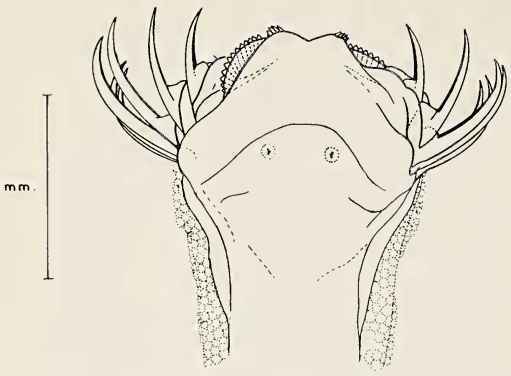

FIG. 7. Head of *S. ferox*.

"it gets mature at 15 mm., while *S. robusta* at about 12 mm. Anterior fins commencing about on a level with the abdominal ganglion. Posterior fins shorter than anterior fins, more on the tail than on the trunk, extending to the seminal vesicles, widest behind the septum. Tail fin generally rounded." And for *S. robusta:* "head fairly large, but smaller than in *S. ferox*. Body proportionally more slender than in *S. ferox*. Anterior fins long, beginning at or just behind the abdominal ganglion. Posterior fins larger than anterior fins (unlike *S. ferox*) more on the tail than on the trunk, widest behind the septum, reaching to the seminal vesiculae when they are bursting." (See Table 2.)

Kofoid (1907) keeps both *S. robusta* and *S. ferox* as valid species.

Michael (1908) identifies both *S. robusta* and *S. ferox* and characterizes *S. robusta* with posterior fins as long or longer than the anterior fins, and *S. ferox* with posterior fins shorter than the anterior fins. The same author in 1911 and 1913

TABLE 1

DIFFERENTIAL CHARACTERISTICS OF *S. robusta* DONCASTER AND *S. ferox* DONCASTER (from Doncaster 1903)

	Sagitta robusta Doncaster	*Sagitta ferox* Doncaster
Length mature, mm	16	12
Tail	¼ of total length	more than ¼ of total length
Head	broad	
Collarette	epidermis thickening behind head	epidermis slightly thickening behind head
Anterior fins	as long as posterior, but narrower, its front end is opposite posterior end of abdominal ganglion	
Posterior fins	reach seminal vesicles	do not quite reach seminal vesicles
Tail fin	reach seminal vesicles	
Corona ciliata	long, narrow; beginning in front of eyes; in shape of an elongated ellipse	resembles that in *S. robusta*
Intestinal diverticula	pair at beginning of intestine	as in *S. robusta*
Ovaries	extremely long; extend in fully mature specimens to anterior transverse septum, so that coelom of trunk becomes almost obliterated	long as in *S. robusta,* but do not quite reach front end of trunk cavity
Seminal vesicles	touch both posterior and tail fins; project somewhat	project only slightly
Hooks	usually 7 or 8	5 or 6, thick and powerful, never more than 6
Anterior teeth	9	6
Posterior teeth	10–14	10

TABLE 2

DIFFERENTIAL CHARACTERISTICS OF *S. robusta* DONCASTER AND *S. ferox* DONCASTER
(from Fowler 1906)

	Sagitta robusta Doncaster	*Sagitta ferox* Doncaster
Length mature, mm	12	15
Body	more slender than in *S. ferox;* strong longitudinal muscles, small lateral fields	firm, broad, opaque owing to longitudinal muscles, trunk of nearly uniform width from ganglion to tail septum; lateral fields narrow
% tail	25–33	26–36
Head	fairly large, larger than in *S. serratodentata,* smaller than in *S. ferox*	large, in expansion broader than body at its broadest
Collarette	distinct, slightly less in breadth and length than in *S. ferox*	well developed, extends to or nearly to anterior fins, powerfully developed in adult specimens
Corona ciliata		commencing in front of eyes, very long, reaching up to ¾ of distance to ganglion or even closer to abdominal ganglion and anterior fins
Anterior fins	long, beginning at or just behind abdominal ganglion, rounded, narrower and shorter than in *S. ferox*	long, widest posteriorly and narrowing forwards, commencing about on a level with abdominal ganglion
Posterior fins	longer than anterior fins, rounded, more on tail than on trunk, widest behind septum, reaching seminal vesicles	shorter than anterior fins, more on tail than on trunk, extending to seminal vesicles when these are tumid, widest behind septum
Hooks	5, 6, or 7 short, strong, broad, strongly curved	5 or 6 short, strong, broad at the base, strongly curved
Anterior teeth	5–8	4–10
Posterior teeth	11–14	9–14

places *S. robusta* under the *S. hispida* synonymy and keeps *S. ferox.*

Ritter-Zahony (1909*a, b;* 1910; 1911*a, b*) places *S. ferox* under the *S. robusta* synonymy.

Baldasserony (1915) reports *S. robusta* and states: "in some specimens the anterior fins reached the posterior end of the ventral ganglion while in others the anterior fins extended to the middle of the ventral ganglion." Accordingly, he recognizes both *S. robusta* and *S. ferox.*

Michael (1919) redescribes both species and gives taxonomic validity to both (Table 3).

Burfield and Harvey (1926) compare the identities of both species with others and *S. ferox* is included under the *S. robusta* synonymy. Burfield and Harvey's drawings no. 33, 34, 35, 37, and perhaps no. 36 do not correspond to *S. robusta,* but agree with *S. ferox.*

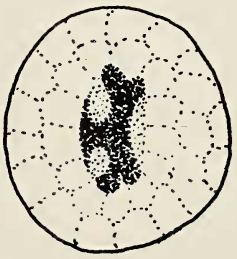

FIG. 8. *S. ferox,* left eye.

In the present article only those publications which give diagnostic details as well as drawings to enforce the identification were considered.

Tokioka (1939) describes *Sagitta ai* as a new species and states at the end of the description:

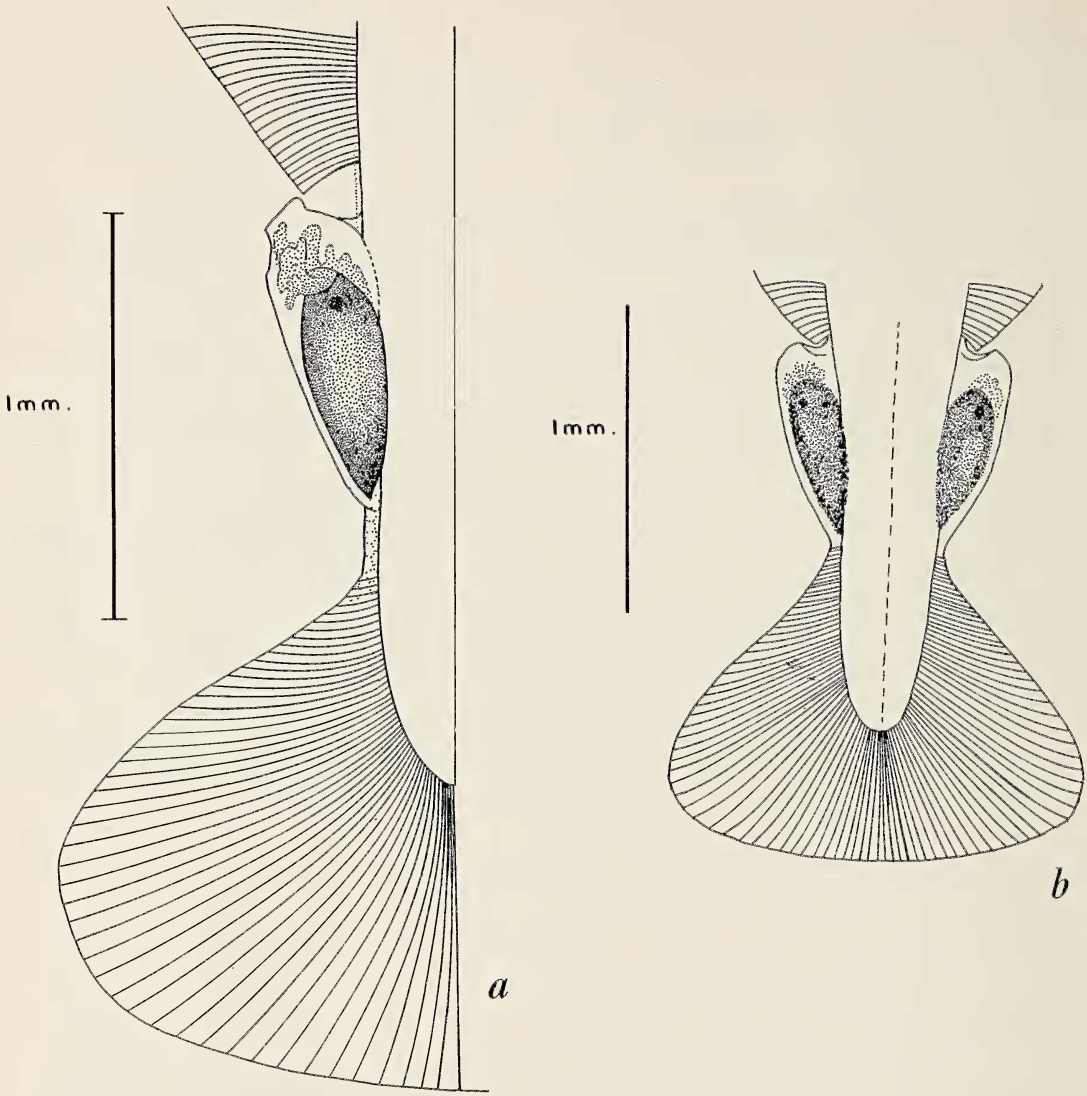

FIG. 9. *S. ferox: a,* Left seminal vesicle, maturity stage IV; *b,* seminal vesicles, dorsal view, maturity stage III.

It is possible that *S. ferox* Doncaster reported by Fowler (1906) from the SIBOGA area is identical with the present species, though there are some differences in the shape of the seminal vesicle, collarette and in some other minute characteristics. However, *S. ferox,* described originally by Doncaster, seems to be not quite identical with the same species reported by Fowler, since there is no characteristic in common to both forms, except for the number of hooks. ... the present form is fished from the surface waters mingled with *S. robusta* with no intermediate form being found, the former is much fewer than the latter.

Sagitta ai Tokioka has morphological characteristics identical to *S. ferox* Doncaster, according to the original description, redescription (Fowler, 1906), and redescription (Michael, 1919).

The description of *Sagitta ai* Tokioka (1939) agrees with *S. ferox* Doncaster but not as to size. It is also identical to that of *S. ferox* Fowler (1906) and Michael (1919), even to the number of hooks. This meristic characteristic is not very helpful for identification purposes as the number of hooks and teeth vary with the changes in the environment, but, strangely enough, in the case of *S. robusta* and *S. ferox* it remains more constant. Perhaps the factors affecting these numerical changes remain at a constant level in the area they occupy.

Because of the general aspect of the body, length of the ovaries, seminal vesicles, and the important characteristic of longer anterior fins than posterior fins, Delman's (1939) drawing of *S. planctonis* is *S. ferox* and not *S. robusta* as Thomson (1947) states, due to the fact that *S. robusta* has shorter anterior than posterior fins.

Tokioka's (1940*a*: 372) description and drawings of *S. robusta* Doncaster and *Sagitta ai* Tokioka, correspond with the redescription for both *S. robusta* and *S. ferox* as well as with the identifications obtained in the present study.

The disposition and proportion of the fins, more than that of the seminal vesicles, suggest that *Sagitta ai* Tokioka (1942) is more likely to be *S. robusta* than *S. ferox* Doncaster. After comparing the seminal vesicles shown in Tokioka's figure 9 (1942: 540) with those of specimen plate VII, figure 3, the conclusion could be drawn that different specimens are involved.

TABLE 3

DIFFERENTIAL CHARACTERISTICS OF *S. robusta* DONCASTER AND *S. ferox* DONCASTER (from Michael 1911, 1913, 1919)

	Sagitta robusta Doncaster	*Sagitta ferox* Doncaster
Length mature, mm	10–14	15.6
% tail	25–33	25–36
Body	opaque	opaque, firm, of uniform width from ventral ganglion to tail septum; muscles broad and firm; lateral fields small
Head		large
Collarette	extends about to halfway from neck to ventral ganglion	long and broad, wider than in *S. robusta*, extends beyond anterior end of ventral ganglion into anterior fins
Anterior fins	do not reach ventral ganglion, shorter than posterior fins	extending anteriorly beyond posterior end of ventral ganglion, frequently past its middle; longer than posterior fins
Posterior fins	longer than anterior fins	extending caudally to seminal vesicles; less than 50% of its length in front of tail septum; triangular in shape, greatest width about midway between septum and seminal vesicles
Corona ciliata		long, commencing in front of eyes and terminating near ventral ganglion
Hooks	5–7	4–6
Anterior teeth	5–10	5–9
Posterior teeth	11–14	10–14
		the anterior half of Michael's (1919) drawing of *S. ferox* is accurate, while second half (disposition of posterior fins and seminal vesicles) is not right

TABLE 4

DIFFERENTIAL CHARACTERISTICS OF *S. robusta* DONCASTER, *S. ferox* f. *americana* TOKIOKA AND *S. ai* TOKIOKA

(from Tokioka 1939, 1940*a*, 1959, 1939, 1940*a*, 1942 respectively)

	Sagitta robusta Doncaster (Tokioka 1939, 1940*a*)	*S. ferox* f. *americana* Tokioka (Tokioka 1959)	*Sagitta ai* Tokioka (Tokioka 1939, 1940*a*, 1942)
Length mature, mm	10–13.5	8.3 (medium size)	16–19.5 individuals 10–13.5 immature
% tail	27.9–32.5	27–29	26.3–30.4
Body			very sturdy, widest between caudal end of anterior fin and front end of posterior fin; lateral fields narrow; muscles well developed
Head	large	medium size	very large, larger than in *S. robusta,* broader than widest portion of body
Collarette	continues to seminal vesicles though thickness decreases between ventral ganglion and anterior part of seminal vesicles, swelling again in front of seminal vesicles	fairly conspicuous at neck, reaches anterior end of ventral ganglion, diminishing in thickness posteriorly; there is a swelling in front of seminal vesicles	fairly conspicuous, extends posteriorly as far as corona ciliata
Anterior fins		begin at the posterior end of ventral ganglion. No rayless zone present	elongated, beginning at the level of the middle of the ventral ganglion, broader at the caudal portion. No rayless zone present
Posterior fins		longer than anterior fins, more on tail than on trunk, widest behind tail septum; small rayless area in front of aperture of female organs	rounded-triangular, as long as anterior fins, being broadest behind tail septum and lying more on tail than on trunk; narrow inner rayless zone in front of tail septum
Eye pigment		covers rather large area, slightly elongated and curved	reniform, apparently
Corona ciliata	head length × 2.5, somewhat wavy in its appearance	begins in front of eyes 1.5 times as long as head, both sides are slightly sinuous	begins just behind brain and stretches posteriorly twice head length, without waving, though marked with sinus between eyes
Intestinal diverticula	conspicuous	very distinct	less remarkable than in *S. robusta*
Ovaries	fill body cavity almost completely	reach neck when fully mature	extend to neck
Seminal vesicles	large, round head and narrow trunk; bursting occurs along ventral lateral size of head; maximum size when ovaries reach maturity	have glandular anterior portion and voluminous sperm sac; in outline resemble those of *S. robusta;* rupture occurs at anterolateral side	head is conspicuous, elongated, slightly larger in anterior portions, which is not as conspicuous as in *S. robusta;* it opens on the lateral side of head
Hooks	7–8	7–8 as in *S. robusta*	6
Anterior teeth	5–7	4–14 (fewer than post. teeth)	7–10
Posterior teeth	11–15	10–12 (9–14)	11–15

Thomson (1947: 14) says: "but in Doncaster's original description *S. robusta* was given as reaching 16 mm. and *S. ferox* only about 13 mm." He, too, is aware of some error in the original description by Doncaster.

Burfield (1950) records only *S. robusta* although *S. ferox* could also be found in that area.

Tokioka (1952) in the list of Chaetognatha includes under the synonymy of *S. ferox* "(*S. hispida* of some authors, *S. japonica* Galzow, *S. robusta* of many authors)," but *Sagitta ai* is placed under the *S. robusta* synonymy. However, the same author (1940*b*) speaks of both *S. robusta* Doncaster and *Sagitta ai* Tokioka.

Tokioka (1955) states: "front end of the anterior fins reaches the middle of the ganglion in *S. robusta.*" This statement does not agree with Tokioka (1940*a*: 372, fig. 5, A) or with Doncaster (1903), Fowler (1906), or Michael (1919).

It is likely that specimens of 22 mm in length are *S. planctonis* or *S. zetesios,* rather than *S. robusta* or *S. ferox* as Thomson (1947) reports.

According to the drawings given by Rao and Ganapati (1958) their *S. robusta* is probably *S. ferox.*

In the Shellback stations where Tokioka (1959) reports *S. ferox* f. *americana,* specimens with the characteristics of *S. robusta* are recorded in this study. It is obvious that Tokioka's description of *S. ferox* f. *americana* agrees with the definition here obtained of *S. robusta* as well as with Tokioka's description of *S. robusta* (1940*a*), but is somewhat smaller. Tokioka (1959) gives for his *S. ferox* f. *americana* a medium size of 8.3 mm long and states that "fully swollen seminal vesicles are found in 6.2 mm. long individuals" (Table 4).

In the present study it was found that *S. robusta* appears with the seminal vesicles well developed when the individuals are still small, and that the species is very protandrous. The seminal vesicles are conspicuous from an early stage to the most advanced stage in the animal's life, unlike those of *S. ferox,* and much like *S. serratodentata* Krohn, *S. pseudoserratodentata* Tokioka, and *S. pacifica* Tokioka.

The specimens recorded from the Shellback Expedition, where Tokioka reports *S. ferox* f. *americana,* have characteristics that agree completely with the previous descriptions of *S. robusta.*

In order to follow as accurately as possible the taxonomic descriptions by the original authors as well as the redescriptions, it was decided that this revision should name *S. robusta* and *S. ferox* the species with the characteristics iden-

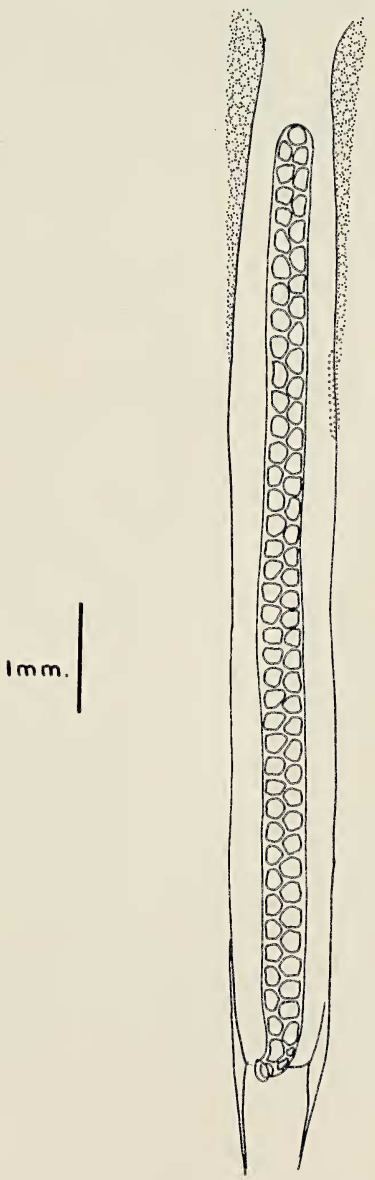

FIG. 10. *S. ferox,* lateral view of right ovary. Detail of disposition of the ova.

TABLE 5

DIFFERENTIAL CHARACTERISTICS OF *S. robusta* DONCASTER AND *S. ferox* DONCASTER FROM THE PRESENT STUDY

	Sagitta robusta Doncaster	*Sagitta ferox* Doncaster
Length mature, mm	8–12	16–18
Average % tail	27.5	26.5
Head	broad	broad
Collarette	well developed, from head to posterior end of ventral ganglion, extending to tail as thin layer thickening in front of anterior end of seminal vesicles	extends from head to anterior end of anterior fins
Anterior fins	shorter than posterior fins, wider than in *S. ferox,* without rayless zone, extending up to level of posterior end of ventral ganglion	reach level of middle of ventral ganglion; they are longer than posterior fins, narrower and longer than in *S. robusta;* no rayless zone present
Posterior fins	rounded, lying more on tail than on trunk, about ⅔ of their length on tail segment; wider at slightly behind or in front of tail septum with small rayless zone in front of tail septum	rounded triangular; wider at a point behind tail septum; they cover same extension on trunk than on tail, or slightly more on latter; a rayless zone extends from tail septum to anterior end of fins
Intestinal diverticula	very conspicuous	conspicuous
Ovaries	long tubes, reaching anterior septum and filling completely body cavity; ova round and arranged in one row	reach neck region, filling completely body cavity; ova arranged in two or three rows
Seminal vesicles	very conspicuous, even in young specimens; they touch both tail and posterior end of posterior fins; a swelling of collarette tissue in tail appears in front of anterior end of seminal vesicles	not so conspicuous as in *S. robusta;* very close to both tail fin and posterior fins
Hooks	7–8	5–6
Anterior teeth	6–9	8–9
Posterior teeth	10–15	12–14

tical to those given to the same species by Fowler (1906) and Michael (1919), and that *Sagitta ai* Tokioka should be classed with *S. ferox,* and *S. ferox* f. *americana* with *S. robusta.*

Tables 1–5, with the respective differential in characteristics for the species from Doncaster, Fowler, Michael and Tokioka's *S. ai* and *S. ferox americana,* give complementary and comparative information.

DISTRIBUTION

S. robusta is equatorial in distribution, extending more to the east than *S. ferox.* It spreads north in the eastern part of the tropical region, invading the waters off Mexico, from the southern part of Baja California southward. The distribution of *S. robusta* (Fig. 11) is more patchy and not as continuous as *S. ferox. S. robusta* was observed mainly in the deeper tows, whereas *S. ferox* appears more often in the upper layers. A difference in the distribution in depth might be the reason for this uneven distribution.

S. ferox occurs along the equatorial and tropical regions of the Pacific, extending northwestwards into the central waters (Fig. 12).

The distribution of *S. robusta* and *S. ferox* reported by Bieri (1959) corresponds respectively to *S. ferox* and *S. robusta.*

FIG. 11. Distribution of *S. robusta* in the Pacific Ocean. Positive stations ○, negative stations ⊙.

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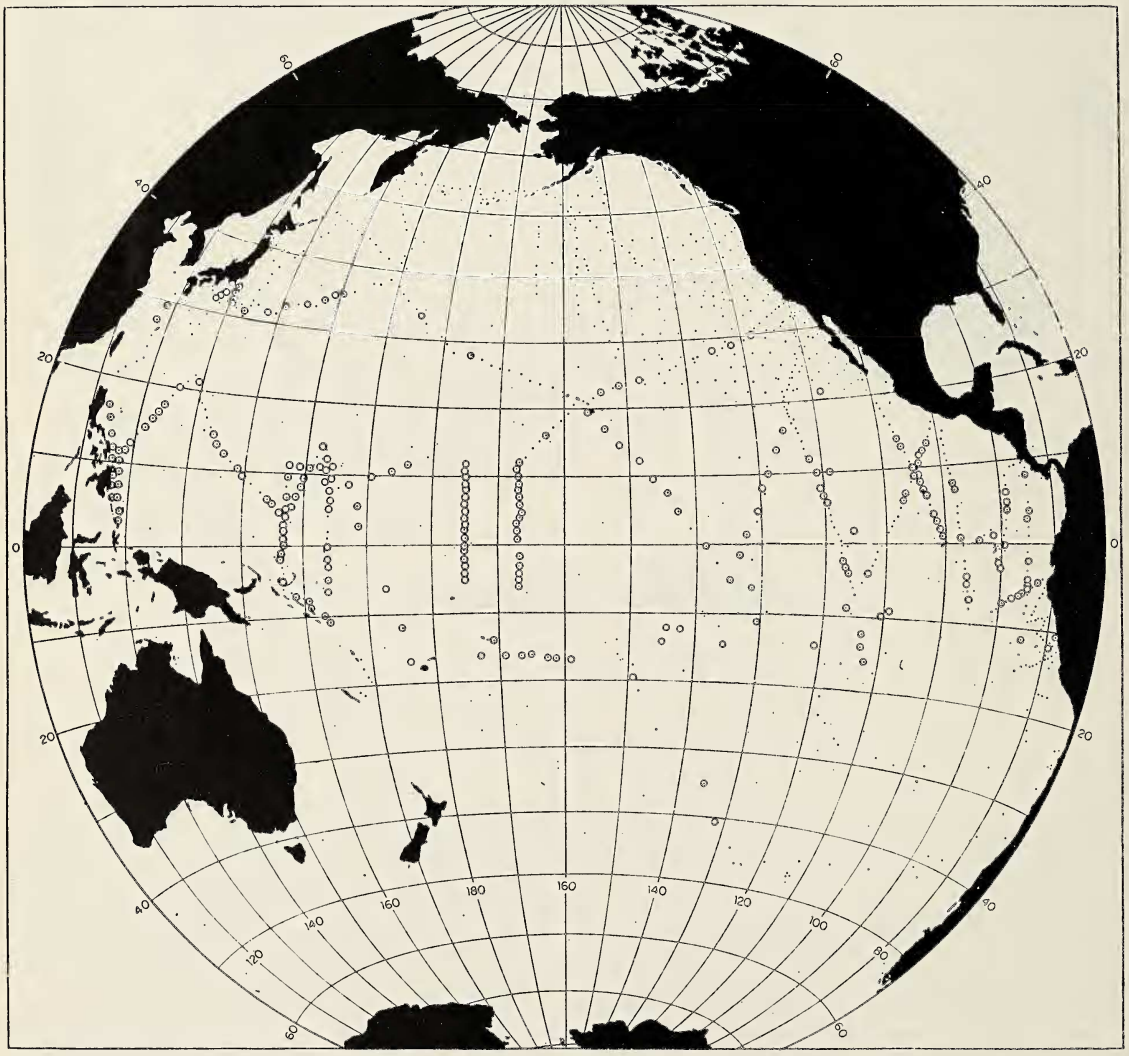

FIG. 12. Distribution of *S. ferox* in the Pacific Ocean. Positive stations ○, negative stations ⊙.

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